TEFLON® FEP 100

Fluorocarbon Resin

Technical Information

Description

TEFLON® FEP 100 fluorocarbon resin is a melt-processible fluorocarbon resin suitable for extrusion as a primary coating onto most gauge wires (AWG #12 and smaller) for twisted-pair constructions and for limited jacketing applications.

As shown in **Table 1**, this resin provides the electrical and mechanical properties needed for low-voltage applications. TEFLON FEP 100 has a melt flow rate that is between TEFLON 3100 and TEFLON FEP 140. This permits a good combination of extrusion speed and stress crack resistance, making TEFLON FEP 100 the insulation of choice for most primary insulation that is more than 7 mils thick.

TEFLON FEP 100 possesses a balance of processing and performance properties which make it the preferred resin for many applications. Like all TEFLON fluorocarbon resins, TEFLON FEP 100 offers an excellent combination of properties: chemical inertness, exceptional dielectric properties, heat resistance, toughness, flexibility, low coefficient of friction, nonstick characteristics, negligible moisture absorption, low flammability, performance at temperature extremes, and weather resistance.

Applications

TEFLON FEP 100 is used in many applications. One of the largest uses is in telecommunications/data cables where TEFLON FEP 100 not only provides excellent fire performance and physical properties but also superior electrical performance. In this role, it is ideal as an insulation for constructions meeting Article 725 and Article 800 of the National Electric Code (NEC) where TEFLON FEP 100 provides superior dielectric properties for rapid, clear signal transmission. Cables insulated with TEFLON FEP 100 have met the requirements of Underwriter's Laboratory UL 910 Steiner Tunnel Test for installation in plenums without metal conduits.

TEFLON FEP 100 is not normally recommended as a jacket material, but it can be used as jacketing for small plenum cables that do not have a braided wire shielding.

Safe Handling

Use of an adequate ventilation system allows safe processing of TEFLON FEP in extruders at high temperatures. For further information, refer to the DuPont bulletin "TEFLON® Fluorocarbon Resin: Safety in Handling and Use," which can be obtained from your DuPont representative.

Packaging

TEFLON FEP 100 is supplied as pellets and is available in 55-lb (24.9-kg) multilayer kraft bags with an integral polyethylene liner.

U.S. Freight Classification

For rail shipments, TEFLON FEP 100 is classified as "Plastic, Synthetic, OTL, NOIBN;" for truck shipments as "Plastic Materials, Granules;" and for express shipments as "Plastics, Synthetic."

TABLE 1
Typical Properties of TEFLON® FEP 100 Fluorocarbon Resin

Property	ASTM Method	Units	Value
Electrical			
Dielectric Constant	D-1531		
100 kHz (10^5 Hz)		–	2.06
1 MHz (10^6 Hz)		–	2.06
Dissipation Factor	D-1531		
100 kHz (10^5 Hz)		–	0.0003
1 MHz (10^6 Hz)		–	0.0006
Dielectric Strength	D-149		
10 mil film		V/mil	2000
1/8 in Sheet		V/mil	510
Mechanical			
Melt Flow Number	D-2116	g/10 min	6.6
Specific Gravity	D-762	–	2.15
Tensile Strength	D-1708	psi	4000
		MPa	27
Elongation	D-1708	%	340
Thermal			
Melting Point	DTA-E168	°C	264
		°F	507

Processing Guidelines for Wire and Cable Use Extrusion Equipment

TEFLON® FEP 100 is fabricated using the same melt processing techniques as other thermoplastics. A brief description of the extrusion equipment used with TEFLON FEP 100 is given here; for more detailed processing information, consult the DuPont "Extrusion Guide for Melt Processible Fluoropolymers," which can be obtained from your DuPont representative.

Molten TEFLON resins are corrosive to many metals; therefore, special corrosion-resistant materials must be used for all parts of extrusion equipment that come into contact with the melt. Nickel-based alloys such as HASTELLOY®, INCONEL®, MONEL®, and XALOY® are the materials of choice. Hardened electroless nickel plate can be used, but even small holes, chips, or cracks in the plating can compromise its performance. Chrome-plated materials are not recommended. Additional information on materials of construction can be obtained from your DuPont representative. Corrosion is likely to occur if dead spots exist in the equipment, processing temperatures are too high or hold-up time is too long. In addition, resin degradation will accelerate corrosion.

A 1.5- to 2.5-inch (38- to 64-mm) extruder with a barrel length-to-diameter ratio of 20:1–30:1 is recommended for extruding TEFLON FEP 100. Extruder barrels should have three to five independently controlled heater zones with temperature controllers capable of accurate operation (±0.6°C/±1°F) in the temperature range of 316°C to 425°C (600°F to 800°F). Heaters should be made of cast bronze or aluminum. Controllers with proportional-integral-derivative (PID) action are recommended.

A 3:1 compression ratio screw consisting of a relatively long feed zone, a 1- to 3-turn transition and a metering section that comprises approximately 1/4 of the length of the screw is recommended. The addition of a mixing section at the end of the screw can improve processibility. Contact your DuPont representative for more information.

A melt thermocouple and melt pressure probe should be installed in the adapter section of the extruder. To obtain an accurate measurement, the thermocouple should extend to the center line of the flow channel.

Degradation of the resin during processing greatly reduces the performance of TEFLON® FEP 100 in stringent applications. Degradation is caused by excessively high melt temperatures, long residence

time in the extruder, and/or excessive shear from the screw. In general, increases in the melt flow number (MFN) greater than 10% during extrusion should be avoided. This 10% rise in MFN will occur after only five minutes at 393°C (740°F) or approximately 45 minutes at 382°C (720°F), but it increases to only 5% after 60 minutes at 360°C (680°F). This indicates the importance of maintaining resin flow through the extruder while at operating temperature and shows why temperatures should be decreased if the extruder is down for even a short period of time.

Other processing conditions that can reduce the resin's performance include melt fracture, very low or uneven melt temperatures, and the presence of hydrocarbon or silicone oils which act as stress crack promoters.

Wire-Coating Techniques

TEFLON FEP 100 is typically applied as a wire insulation using tubing techniques. Draw-down ratios (DDR) generally ranging from 50:1 to 200:1 are common, with higher DDRs usually allowing greater line speed. A draw-ratio balance (DRB) ranging from 0.9 to 1.1 is recommended. A complete discussion of DDR and DRB can be found in the DuPont "Extrusion Guide for Melt Processible Fluoropolymers," which can be obtained from your DuPont representative.

A controlled vacuum is required at the rear of the crosshead to adjust the melt cone to the desired length. A melt cone that is too long results in excessive caliper variations while a melt cone that is too short results in excessive spark failures and cone breaks. Laboratory experience has shown that a cone length of 2.5 in to 3.0 in (64 mm to 76 mm) yields satisfactory results with a DDR of 156:1 and a DRB of 1.00. Control can be achieved at a shorter cone length if a higher DRB is used.

An electronic wire preheater located as close to the crosshead as possible is recommended for preheating the wire. Although the amount of preheat will depend upon the application, the preheater should be capable of heating the wire to 149°C to 204°C (300°F to 400°F) while operating at a typical line speed of 500 ft/min (152 m/min).

Stationary pulleys should be located on both sides of the crosshead to reduce wire flutter. The wire should pass through the crosshead, without touching the crosshead or the extrusion tip. Sponges should not be used to reduce flutter downstream of the crosshead because they can produce insulation faults.

The coated wire should pass through a 1- to 5-ft (0.3- to 1.5-m) air gap followed by a warm-water quench at 38°C to 66°C (100°F to 150°F) to allow uniform cooling and prevent the formation of shrinkage voids in the insulation. The cooling is highly dependent on the thickness of the insulation.

Processing conditions depend on the equipment size and line speed. **Tables 2** and **3** list the actual processing conditions for a 10-mil wall of TEFLON FEP 100 on a 24 AWG copper wire. Adjustments may be necessary for other equipment.

Color Concentrates

TEFLON FEP based color concentrates are commercially available from several manufacturers. Only inorganic pigments should be used due to the high temperatures used to process TEFLON FEP. Concentrate loading information is available from the manufacturer, and it will normally depend on the compositions of concentrate, wire size, insulation thickness, and intensity of color desired. Your DuPont representative can provide additional information on suppliers.

Band Marking

Band marking inks for TEFLON FEP are commercially available from several manufacturers. In-line band marking of TEFLON FEP can be accomplished by positioning the band marking unit as close to the crosshead as possible and by using inks with high-boiling solvents. Your DuPont representative can provide additional information on suppliers.

TABLE 2
Typical Temperature Profile for Extruding TEFLON® FEP 100 on AWG #24 Solid Copper Wire[1]

Zone	°C	°F
Rear Zone[2]	366	690
Rear Center[2]	382	720
Center	388	730
Front Center	393	740
Front	396	745
Clamp	396	745
Adapter	396	745
Crosshead	396	745
Die Holder	416	780
Melt	393	740

[1]Based on a 60-mm extruder with a 30:1 L/D; adjustments may be necessary for other equipment.

[2]For a smaller machine, it will be necessary to raise the temperature to ensure that the resin is completely melted before entry into the extruder's transition zone. A surging output at the die could be caused by incomplete melting.

TABLE 3
Typical Operating Conditions for Extruding TEFLON® FEP 100 on AWG #24 Solid Copper Wire[1]

Extruder Speed	rpm	8
Line Speed	ft/min	500
	m/min	335
Wire Preheat	°C	152
	°F	240
Pressure	MPa	4.6
	psig	670
Die	in	0.500
	mm	12.70
Tip	in	0.250
	mm	6.35
DDR	–	156:1
DRB	–	1.00

[1]Based on a 60-mm extruder with a 30:1 L/D; adjustments may be necessary for other equipment.

(8/91) 220312A Printed in U.S.A.
[Replaces: H-26580]
Replaces No.: H-26580-1

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Product Information

DuPont™ Teflon® FEP 6100

fluoropolymer resin

Brand

Teflon® is a registered trademark of DuPont for its brand of fluoropolymer resins, which can only be used when licensed by DuPont. Customers who wish to use the *Teflon*® trademark in connection with DuPont FEP products in approved applications should contact (800) 262-2745. Without a license, customers may not identify their product as containing *Teflon*®, but may refer to the resin as FEP 6100.

Description

DuPont™ *Teflon*® FEP 6100 fluoropolymer resin is a melt-processable fluoropolymer resin specifically designed for high-speed extrusion of thin coatings on small-gauge wires for twisted-pair constructions.

As shown in **Table 1**, this resin provides the electrical and mechanical properties needed for low-voltage applications. In addition, *Teflon*® FEP 6100 has a higher melt flow rate than most other fluoropolymer resins. This permits higher extrusion speeds and easier processing, making *Teflon*® FEP 6100 a cost-effective alternative for producing thin-wall extrusions.

Teflon® FEP 6100 possesses a balance of processing and performance properties, which makes it an excellent choice for many applications. Like all *Teflon*® fluoropolymer resins, *Teflon*® FEP 6100 offers an excellent combination of properties:

- low flammability
- exceptional dielectric properties
- heat resistance
- toughness
- flexibility
- low coefficient of friction
- nonstick characteristics
- negligible moisture absorption
- chemical inertness
- performance at temperature extremes
- weather resistance

Applications

Teflon® FEP 6100 is especially suitable for use in insulating data and telecommunications cables with excellent fire performance and physical properties as well as outstanding electrical performance. Cables insulated with *Teflon*® FEP 6100 have met the requirements of the NFPA 90A 'Standard for the Installation of Air-conditioning and Ventilating Systems'. To meet these requirements cables are tested using the NFPA 262 Standard Method of Test for Flame Travel and Smoke of Wires and Cables. This standard test method is used to qualify cables for installation in plenum spaces under the provisions of NFPA 90A. *Teflon*® FEP 6100 complies with ASTM 2116.

Teflon® FEP 6100 is not recommended as a jacket material or as a heavy-walled insulation in constructions where significant thermal cycling may raise stress-cracking concerns.

Safety Precautions

WARNING!

VAPORS CAN BE LIBERATED THAT MAY BE HAZARDOUS IF INHALED

Before using *Teflon*®, read the Material Safety Data Sheet and the detailed information in the "Guide to the Safe Handling of Fluoropolymer Resins", latest edition, published by the Fluoropolymers Division of The Society of the Plastics Industry —available from your DuPont representative.

Open and use containers in well-ventilated areas using local exhaust ventilation (LEV). Vapors and fumes liberated during hot processing, or from smoking tobacco or cigarettes contaminated with *Teflon*® FEP 6100, may cause flu-like symptoms (chills, fever, sore throat) that may not occur until several hours after exposure and pass within 36 to 48 hours. Vapors and fumes liberated during hot processing should be exhausted completely from the work area; contamination of tobacco with polymers should be avoided.

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Table 1
Typical Properties of DuPont™ *Teflon*® FEP 6100 Fluoropolymer Resin

Property	ASTM Test Method	Unit	Typical Value
Electrical			
Dielectric Constant	D2520		
100 kHz (10^5 Hz)		—	2.05
1 MHz (10^6 Hz)		—	2.03
600 MHz		—	2.00
Dissipation Factor	D2520		
100 kHz (10^5 Hz)		—	±0.00006
1 MHz (10^6 Hz)		—	0.00057
600 MHz ($6x10^8$ Hz)		—	0.00088
Physical			
Melt Flow Number	D2116	g/10 min	30
Melting Point	D3418	°C (°F)	264 (507)
Tensile Strength	D1457	MPa (psi)	20 (3,000)
Elongation	D1457	%	300
Flexural Modulus	D790A	MPa (psi)	520 (75,500)
Specific Gravity	D792	—	2.14

Packaging

Teflon® FEP 6100 fluoropolymer resin is supplied as pellets and is available in 25-kg (55.1-lb) plastic bags. This product is also available in 1000-kg (2204-lb) bulk containers.

U.S. Freight Classification

For rail shipments, *Teflon*® FEP 6100 is classified as "Plastic, Synthetic, O.T.L., NOIBN;" for truck shipments as "Plastic Materials, Granules;" and for express shipments as "Plastics, Synthetic."

Processing Guidelines for Wire and Cable Use

Extrusion Equipment

Teflon® FEP 6100 is fabricated using the same melt processing techniques as other thermoplastics. A brief description of the extrusion equipment used with *Teflon*® FEP 6100 is given here; for more detailed processing information, consult the DuPont bulletin "*Teflon*®/*Tefzel*® Melt Extrusion Guide," which can be obtained from your DuPont representative.

Molten fluoropolymer resins are corrosive to many metals; therefore, special corrosion-resistant materials must be used for all parts of extrusion equipment that come into contact with the melt. Corrosion is likely to occur if dead spots exist in the equipment, processing temperatures are too high, or hold-up time is too long. In addition, resin degradation will accelerate corrosion. Nickel-based alloys such as Hastelloy[a], Inconel[b], Monel[b], and Xaloy[c] are the materials of choice. Hardened nickel plate can be used, but even small holes, chips, or cracks in the plating can compromise its performance. Chrome-plated materials are not recommended. Additional information on materials of construction can be obtained from your DuPont representative.

A 1.5- to 2.5-in extruder with a barrel length to diameter ratio of 28:1 or higher is recommended for extruding *Teflon*® FEP 6100. Extruder barrels should have four to five independently controlled heater zones with temperature controllers capable of accurate operation (±0.6°C[±1°F]) in the temperature range of 316 to 425°C (600 to 800°F). Heaters should be made of cast bronze or aluminum.

Controllers with proportional-integral-derivative (PID) action or equivalent are recommended.

A 3:1 compression ratio screw consisting of a relatively long feed zone, a 3 to 5 turn transition, and a metering section that comprises 5 to 7 turns is recommended. The addition of a Saxton mixing section at the end of the screw can improve processability.

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[a] Hastelloy is a registered trademark of Cabot Corporation, Kokomo, IN.

[b] Inconel and Monel are registered trademarks of International Nickel Company, Huntington, WV.

[c] Xaloy is a registered trademark of Xaloy Inc., New Brunswick, NJ.

Contact your DuPont representative for more information.

A melt thermocouple and melt pressure probe should be installed in the adapter section of the extruder. To obtain an accurate measurement, the thermocouple should protrude into the melt flow sufficient to measure its temperature, not the metal surrounding it.

Degradation of the resin during processing greatly reduces the performance of *Teflon*® FEP 6100 in stringent applications. Degradation is caused by excessively high melt temperatures, long residence time in the extruder, and/or excessive shear from the screw. In general, increases in the melt flow number (MFN) greater than 10% during extrusion should be avoided.

Other processing conditions that can reduce the resin's performance include melt fracture, very low or uneven melt temperatures, and the presence of hydrocarbon or silicone oils, which act as stress-crack promoters.

High-Speed Wire Coating Techniques

Considerable experimentation has gone into the development of *Teflon*® FEP 6100. This work has resulted in a resin which when processed within the recommended processing parameters will give a reliable, consistent manufacturing process for insulating wire. As with other *Teflon*® FEP grades, FEP 6100 is applied as a wire insulation using tubing extrusion techniques. The Draw Down Ratio (DDR) aim should be 90:1 centering it in the window 80 to 100 DDR. The Draw Ratio Balance (DRB) should be in the range of 1.04 to 1.10. There is a complete discussion of DDR and DRB, including how they can be calculated, in the DuPont bulletin, "*Teflon*®/ *Tefzel*® Melt Extrusion Guide".

The melt temperature of the extrudate is critically important to the wire coating process. The melt temperature aim should be 394°C (741°F), centered in the window 390°C (734°F) to 398°C (748°F). Melt temperature cannot be reliably predicted by temperature profiles, as it will also vary with throughput. Melt temperature should be independently measured by an in-stream probe at the adapter, or by some other proven reliable means. An electronic wire preheater (or in-line wire draw annealer), located as close to the crosshead as possible, is recommended for preheating the wire to 105 to 176°C (220 to 350°F). A controlled vacuum is required at the rear of the crosshead to adjust the melt cone to the desired length. Experiments have shown cone lengths from 38 mm to 57 mm (1.5 to 2.25 inch) yield satisfactory results with 80 to 100 DDR.

Stationary pulleys should be located on both sides of the crosshead to reduce wire flutter. The wire should pass through the crosshead without touching the inside of the head or the extrusion tooling. Sponges should not be used to reduce flutter downstream from the crosshead because they tend to cause insulation faults.

The coated wire should pass through a long, air-filled, ventilated by LEV, cooling trough. Where the trough cannot be long enough to cool the FEP sufficiently to avoid deformation on wind-up, consideration should be given to the use of a short hot water bath at the extruder end of the trough. Processing conditions will depend on the equipment used, the product being made and the production rates needed. Further advice is available through a DuPont Sales Representative.

Color Concentrates

Your DuPont representative can provide information on suppliers of color concentrates.

Band Marking

Band marking inks for *Teflon*® FEP are commercially available from several manufacturers. In-line band marking of *Teflon*® FEP can be accomplished by positioning the band-marking unit as close to the crosshead as possible and by using inks with high-boiling solvents. Your DuPont representative can provide additional information on suppliers.

For more information on Fluoroproducts: (302) 479-7731

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(8/02) RWJ192 Printed in U.S.A.
Reorder No.: H-96492